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Assessing the Influence of Project Uncertainty and IT-Usage on Knowledge Integration in Software Teams*

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ABSTRACT

Organizational knowledge resources typically exist in specialized pockets scattered across the firm. As distributed knowledge systems, firms' capacity to manage their knowledge resources is linked with their ability to integrate these pockets of specialized knowledge. Firms are increasingly depending on teams to strategically consolidate their dispersed knowledge into productive outcomes. Teams integrate knowledge from external sources with internal knowledge such as skills, know-how, and expertise of their members to create project outcomes. The aim of this research will be to examine how knowledge integration in software teams is influenced by project uncertainty and IT-usage.

Keywords: Knowledge Integration; Project Uncertainty

INTRODUCTION

Although firms have engaged in knowledge creation, accumulation, and application for many years, only recently has knowledge been identified as a strategic resource (Grant 1996a). Defined as a "fluid mix of framed experience, values, contextual information, and expert insight" (Davenport and Prusak 1998), knowledge underlies a firm's products and services. To remain competitive, firms must find ways to better manage their knowledge resources. However, knowledge typically exists in specialized pockets scattered across the firm and becomes a valuable corporate asset only if it is widely accessible (Nonaka 1991). Thus, a firm's capacity to manage its knowledge resources is linked with its ability to better integrate its dispersed pockets of specialized knowledge (Tsoukas 1996). Teams, supported by information technologies, are better able to facilitate this integration, as compared to individual employees (Faraj and Sproull 2000).

Organizations are increasingly adopting team-based structures to strategically consolidate their knowledge resources (Lipnack and Stamps 1997). Team members possess diverse

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knowledge resources, and teams perform knowledge integration, which is defined as the process of absorbing knowledge from external sources and blending it with internal knowledge resources, to bear upon the project outcomes (Cohen and Bailey 1997).

Software projects are an appropriate example of team-level knowledge integration. Multiple project stakeholders, within and outside software teams, possess diverse portfolios of know-how, skills, and abilities that teams must integrate to produce project outcomes (Tiwana 2003). Prior research suggests that software teams carry out two types of knowledge integration - *external integration*, i.e., absorbing new knowledge from external sources, and *internal integration*, which includes combining internally available knowledge into collective (project) knowledge (Tiwana, Bharadwaj et al. 2003). In light of this observation, two issues merit attention: what are some of the antecedents to a software team's knowledge integration? And, what is the nature of their influence?

Past literature identifies two categories of antecedents: (1) project characteristics such as uncertainty (Zmud 1983; Anand, Clark et al. 2003); and (2) the team's usage of various information technologies (IT) (Guinan, Coopridge et al. 1998; Alavi and Leidner 1999).

This brings us to our second issue – how these antecedents influence knowledge integration in software teams? We focus on this issue in our research by addressing following questions:

1. How does project uncertainty influence knowledge integration in software teams?
2. How does a software team's usage of various IT-based systems moderate the influence of project uncertainty on team's knowledge integration?

ANTECEDENTS TO KNOWLEDGE INTEGRATION

Project Uncertainty

Zmud (1980) related software project uncertainty to the lack of critical knowledge inputs in various project-related areas. Project uncertainty is a key practical problem in effective management of software projects (McFarlan 1981). For the purpose of this study, project uncertainty is defined as the inadequacy of information inputs regarding requirements specifications, which reduces the team's ability to predict project outcomes. Thus, project uncertainty was assessed in terms of requirements uncertainty and outcome uncertainty.

Zmud (1980) proposes that software teams need to understand constantly changing software requirements, and thus anticipate, plan, and control the development efforts accordingly. To carry out their activities, teams need to regularly absorb specifications-related inputs from the external environment (Curtis, Krasner et al. 1988; Kraut and Streeter 1995). Previous research suggests that sourcing these inputs through vertical coordination between the project manager and the users, can reduce project uncertainty (Nidumolu 1995). Teams working on uncertain projects also coordinate vertically with other groups, such as top management, to obtain slack knowledge resources (Galbraith 1977). Once obtained, the requirements-related inputs and the slack resources can then be integrated with the team's internal knowledge resources to buffer the project from hazards of "requirements creep" (Nidumolu 1995).

Teams working on uncertain projects also initiate informal horizontal communication with external sources to reduce uncertainty (Galeghar and Kraut 1994; Andres and Zmud 2001). It has been observed that members of such teams typically have widespread external networks (Kraut and Streeter 1995). Members compensate for their knowledge scarcity by frequently seeking and integrating knowledge inputs from these networks (Anand, Clark et al. 2003; Hoegl, Weinkauff et al. 2004).

Based on these arguments, it can be proposed that teams working on uncertain projects fulfill their knowledge scarcity by integrating knowledge from both internal and external sources. Therefore, we hypothesize:

Hypothesis 3a: Project uncertainty positively influences a software team's internal knowledge integration.

Hypothesis 3b: Project uncertainty positively influences a software team's external knowledge integration.

Moderating Influence of IT Usage

This study examines the usage of two categories of IT-based systems - collaborative systems (e.g., corporate intranets, e-mail, telephone, list serves, and group support systems) (Jarvenpaa and Staples 2000) and KM systems (e.g., electronic knowledge repositories, expert directories, and electronic forum software) (Kankanhalli, Tan et al. 2005).

To examine IT moderation, we utilize the theory of task-technology fit, as per which for information technologies to have a positive impact on individual performance, they must be a good fit with the task they support (Constant, Keisler et al. 1994). The lack of knowledge inputs in uncertain projects may require interactive, expressive communication among team members (Zmud, Lind et al. 1990). People working on uncertain tasks thus prefer communicating face-to-face (Struas and McGrath 1994). Thus, using IT-based systems for this purpose may be detrimental to team's internal communications, which may negatively influence team's efforts to integrate its internal knowledge resources. Thus, it is expected that IT-usage will actually impede internal knowledge integration in teams working on uncertain projects. We propose:

Hypothesis 2a: IT-usage will moderate the influence of project uncertainty on a software team's internal knowledge integration.

On the contrary, teams working on uncertain projects can use IT-based systems to search for and access external knowledge inputs. For example, listserves and electronic forums can be used to contact external experts, or technical white papers and project knowledge documents can be accessed from the knowledge management system. Though, these inputs, once acquired, may be better integrated within the team in face-to-face settings. Thus:

Hypothesis 2b: IT-usage will moderate the influence of project uncertainty on a software team's external knowledge integration.

RESEARCH METHODOLOGY

Where available, constructs were measured using standard scales from prior studies to enhance validity (Stone 1978). Where existing scales were absent, new items were developed from the previous literature. Items for internal knowledge integration (IKI) have been modified from the previous studies in the area, as well as in the areas of knowledge transfer and organizational learning (Tempelton, Lewis et al. 2002; Tiwana and McLean 2005). Previous studies in knowledge acquisition, knowledge transfer, and organizational learning have contributed to the items for external knowledge integration (Tempelton, Lewis et al. 2002; Ko, Kirsch et al. 2005). Based on previous studies, project uncertainty was measured in terms of requirements uncertainty (RU) and outcome uncertainty (OU). Requirements uncertainty (RU) was measured in terms of the instability and diversity of project requirements (Nidumolu 1995), while outcome uncertainty (OU) was measured in terms of the unpredictability of project outcomes (Van de Ven, Delbecq et al. 1976). To conduct a robust assessment of teams' IT-usage, two separate sets of items were developed – one set to measure the *nature* of IT-usage (ITU) and the other set to measure the *frequency* (ITF) of IT-usage.

A preliminary test of the resulting 20 items* was then conducted to further examine their content validity, construct validity, and reliability. Scales included 7-point Likert anchors ranging from strongly disagree (=1) to strongly agree (=7). The questionnaire was administered to 50 project leaders in a capability maturity model (CMM) Level 5 software services firm. Based on the results of the preliminary test, all 20 items were retained for the final questionnaire.

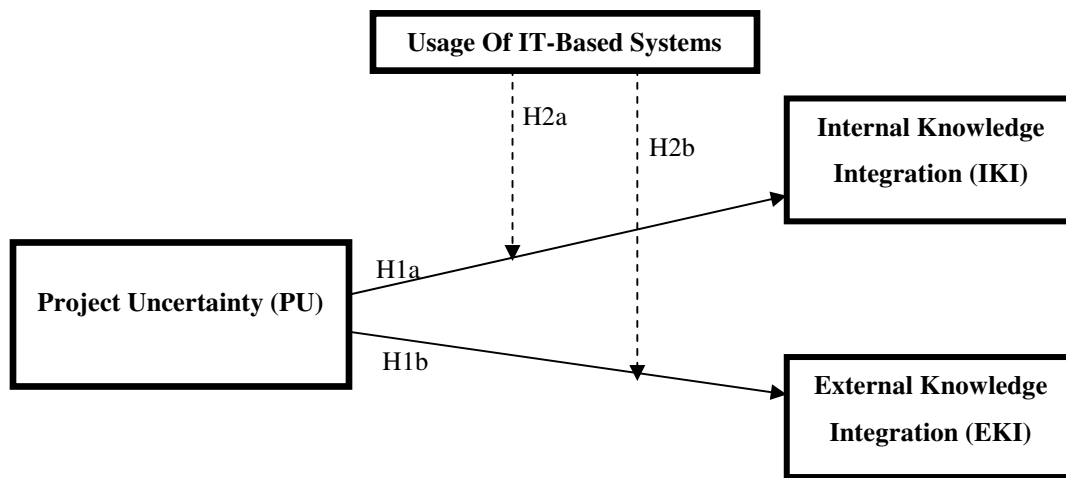


Figure 1. Research Model Indicating Hypotheses

Final data was collected through an online questionnaire-based survey administered to 225 project leaders in nine software firms. The nine firms provide custom-made software solutions to Fortune 1000 clients. They were chosen because of similarity in their nature of

* Items are available on request from the first author.

operations. Additionally, all the firms are CMM Level 5 companies, which ensured consistency of their software development processes. Project leaders were chosen as respondents as they have a better understanding than others (e.g. project managers) regarding project-related issues. 161 project leaders completed the questionnaire, resulting in a 71.56 percent response rate. Of the 161 responses, eleven were incomplete, and were excluded from subsequent analyses.

DATA ANALYSES AND RESULTS

Partial least squares (PLS) technique was used to validate the measurement model and to test the hypothesized relationships. PLS is a second-generation structural equation modeling technique that utilizes a correlational, principal component-based approach to estimation (Majchrzak, Beath et al. Forthcoming). PLS is a favorable technique for causal-predictive analysis in situations characterized by early stages of theory development (Kankanhalli, Tan et al. 2001). As this study is an early attempt to develop a theoretical framework of teams' knowledge integration, PLS is an appropriate technique for this study. Additionally, PLS is recommended above ANOVA and regression in research situations involving moderator analysis (Chin, Marcolin et al. 2003).

Measurement Model

The measurement model was assessed by examining the internal consistency, convergent validity, and discriminant validity of the constructs (Hulland 1999). All constructs exhibit the desired characteristics (Table 1). All constructs load highly and significantly on their respective construct and have low cross-loadings on other constructs. Internal consistency is assessed with the help of composite reliabilities (ρ_c), which avoid the assumption of equal weighting of items. An estimate of convergent validity is average variance extracted (AVE). All AVE values are higher than the recommended value of 0.5 (Fornell and Larker 1981). AVE values can also be used to examine the discriminant validity. Comparing the square root of each AVE value (bold figures on the diagonal in Table 2, representing the average association of each construct to its measures), with the correlations among constructs (the off-diagonal figures) points out the closeness of association of each construct to its measures than to the measures of other constructs.

Table 1. Reliability and Validity

Construct	# of Items	PLS Loadings (T-statistic)	Composite Reliability (ρ_c)	AVE	IKI	EKI	ITU	ITF	RU	OU
Internal Knowledge Integration (IKI)	4	.86 (22.41); .91 (37.88); .87 (32.12); .90 (55.63)	0.940	0.796	0.892					
External Knowledge Integration (EKI)	3	.78 (16.04); .77 (16.63); .87 (34.84)	0.852	0.659	0.565	0.811				
Nature of IT-Usage (ITU)	3	.88 (29.06); .95 (88.55); .91 (33.32)	0.872	0.694	0.307	0.480	0.833			
Frequency of IT-Usage (ITF)	4	.90 (38.78); .94 (65.83); .90 (35.96); .93 (57.13)	0.959	0.855	0.322	0.466	0.707	0.924		
Requirements Uncertainty (RU)	3	.77 (19.27); .88 (42.36); .83 (25.30)	0.872	0.694	-0.223	-0.234	-0.174	-0.179	0.833	
Outcome Uncertainty (OU)	3	.88 (27.31); .93 (76.24); .93 (86.79)	0.994	0.848	-0.368	-0.237	-0.170	-0.048	0.473	0.920

A more conservative estimate is to compare the AVE values themselves (square roots of AVE values are higher than the values themselves) to the correlations. This comparison also supports the discriminant validity of the constructs.

Structural Model

In PLS, paths are interpreted as standardized regression weights. Thus, assessing the structural model involves estimating the magnitude, sign, and statistical significance of path coefficients in the model. Separate main-effects models were assessed for external knowledge integration and internal knowledge integration. A bootstrapping method using 500 re-samples was used to determine the statistical significance of the parameter estimates.

Moderating effect of IT-usage was examined using the method proposed by Chin et al. (2003), as per which moderation is examined by introducing an interaction term in the main-effects model. Similar to the main-effects analysis, moderation effects were also assessed separately for external knowledge integration and internal knowledge integration respectively.

Main Effects Analysis. Project uncertainty is significantly related to both internal knowledge integration (path coefficient = -0.286, $p < .001$) and external knowledge integration (path coefficient = -0.271, $p < .001$). But the effect of project uncertainty is in direction opposite as hypothesized, thereby refuting both Hypotheses 1a and 1b. The results of main effects analyses are presented in Figure 2.

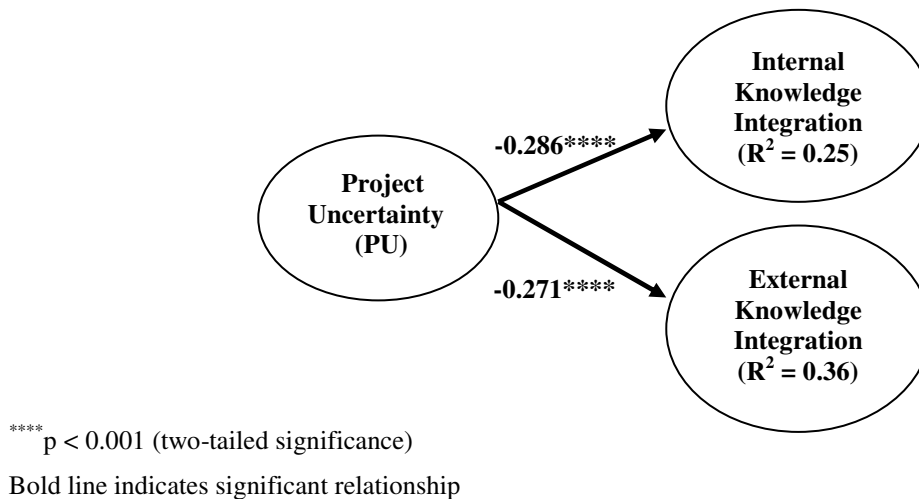
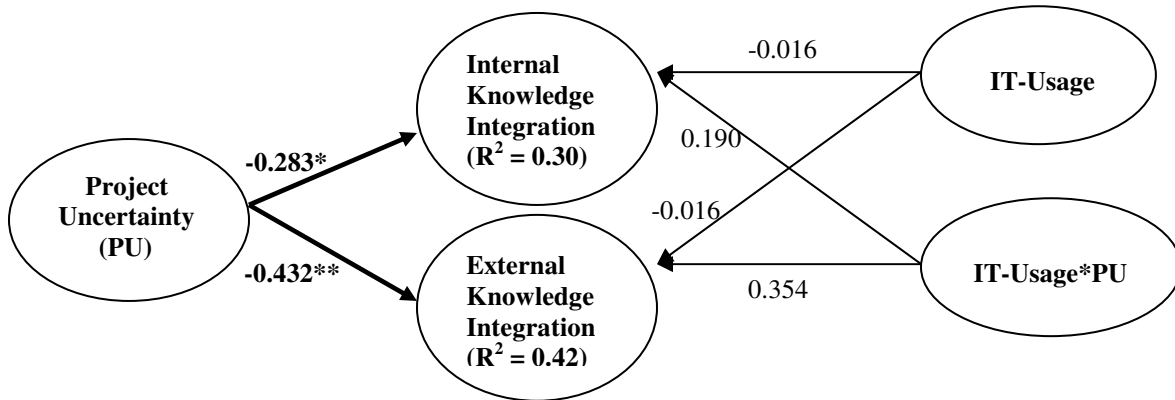


Figure 2. Model Indicating Main Effects

Moderation Effects Analysis. Contrary to expectations, IT-usage did not moderate the influence of project uncertainty on internal knowledge integration as well as external knowledge integration. Thus, Hypotheses 2a and 2b were not supported. In the absence of hypothesized moderation, the main-effects of project uncertainty as well as IT-usage were examined. Project uncertainty was found to be significantly associated with internal knowledge integration (path coefficient = -0.283, $p < .10$) and external knowledge integration

(path coefficient = -0.432, $p < .05$). Main-effects of IT-usage were not significant. The results of moderation effects analyses are presented in Figure 3. Table 2 summarizes all the results. R^2 values of all models are in excess of 25 percent.



* $p < 0.10$; ** $p < 0.05$ (two-tailed significance)

Bold line indicates significant relationship.

Figure 3. Model Indicating Moderation Effects

Table 2. Summary of Results					
	Hypothesis	Standardized Path Coefficient	t-value for Path	Result	R^2
H1a	Project Uncertainty → Internal Knowledge Integration	-0.286****	3.776	Not Supported	0.25
H1b	Project Uncertainty → External Knowledge Integration	-0.271****	4.739	Not Supported	0.36
H2a	IT-Usage* Project Uncertainty → Internal Knowledge Integration	0.190	0.936	Not Supported	0.30
H2b	IT-Usage* Project Uncertainty → External Knowledge Integration	0.354	1.456	Not Supported	0.42

**** $p < 0.001$ (two-tailed significance)

DISCUSSION

Results of this study suggest that a software team's capability to integrate internal knowledge deteriorates as project uncertainty increases. Results do not confirm to the hypothesized theory, and thus need in-depth explanation that may alter our understanding of factors underlying the existing theory. Prior theory defines software project uncertainty as the lack of critical knowledge inputs in various project-related areas (Zmud 1980). Thus, it is expected that, as compared to their less certain counterparts, more uncertain projects are more likely to seek and integrate knowledge from internal as well as external sources. But, this expectation is based on the assumption that uncertainty in software projects only influences the availability of critical knowledge, to the exclusion of any other influence. This is highly

unlikely. Uncertainty has a negative influence on other aspects of the project also. For example, the ambiguity inherent in uncertain projects may prevent a clear understanding among the team members about project-related issues, and the team may have to make frequent changes in role allocations, schedules, and priorities (Galbraith 1973; Van de Ven, Delbecq et al. 1976). These changes may also prevent the formation of a shared context among the members. The situation may be aggravated by multiple connotations of various project-related issues among the team members. Additionally, differences of opinion among the members may become more pronounced in situations involving uncertainty. As Kraut and Streeter explain: “Software is uncertain because different subgroups involved in its development often have different beliefs about what it should do and how it should do it.....While analysts may try to adopt the point of view of the software’s users, designers and programmers often have a more technical focus, with an emphasis on ease of development and efficiency of computation. As more groups become involved in software development, disagreements among them inevitably increase” (1995: 70).

These issues, which are typical to uncertain projects, may challenge the project teams’ capability to synthesize their internal knowledge resources to develop systemic project-level knowledge, and to use that knowledge to achieve project goals.

The negative influence of project uncertainty on external knowledge integration is another interesting result of this study, which does not confirm to existing theory. Current theoretical perspectives argue that in uncertain projects, the instability of various project-related issues (e.g., requirements specifications) necessitates the software teams to keep themselves informed of the most recent updates on those issues (Zmud 1980). Thus, teams need to regularly absorb knowledge inputs from the external environment (Curtis, Krasner et al. 1988; Kraut and Streeter 1995), which compels them to initiate horizontal coordination with the external sources (Galeghar and Kraut 1994; Andres and Zmud 2001). It was also argued that teams working on uncertain projects may also need to coordinate vertically with other groups, such as the top management, to obtain slack knowledge resources (Galbraith 1977). Some studies have found that teams’ vertical and horizontal coordination with external entities (as is typical to uncertain projects) overwhelms teams’ information-processing capacities (Argote 1982), which may explain the deterioration in teams’ ability to integrate external knowledge resources.

The results of IT moderation suggest that IT-usage did not moderate the negative influence of project uncertainty on both internal and external knowledge integration. The results, although contrary to the hypotheses, align with the theory of information richness, which argues that situations involving multiple and conflicting viewpoints require communication through information-rich channels (Daft and Lengel 1986; Daft, Lengel et al. 1987; Struass and McGrath 1994). Thus, situations involving high uncertainty may benefit more from frequent person-to-person communications (Kim 1988). What is surprising, though, is the lack of IT-moderation on external knowledge integration. In light of the negative influence of uncertainty on external knowledge integration, it is possible that teams working on uncertain projects are not even sure of what knowledge to acquire from external sources. Thus, whether the team uses IT-based systems to integrate external knowledge inputs or not may not matter.

CONCLUSION

This study examines the influence of project uncertainty and IT-usage as antecedents to internal and external knowledge integration in software development teams. The empirical results from this study are expected to help academics and practitioners alike. In academia, the discussion of a team's knowledge integration is a relatively new area of exploration, and this study builds upon the few but nonetheless significant past research inquests within in the fields of IS, KM, teams, and boundary spanning. Thus, the results of this study will interlink these fields and provide a foundation for future inter-disciplinary research.

For practitioners, it is expected that the results of this study will improve their understanding of knowledge integration *within* their core building blocks of team-based organizations. Second, the results will help managers develop a knowledge integration profile of their teams and projects. For example, they can identify the characteristics of teams that are more of 'external knowledge integrators' versus those that are 'internal knowledge integrators'. Managers can use this information while developing their future KM strategy.

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